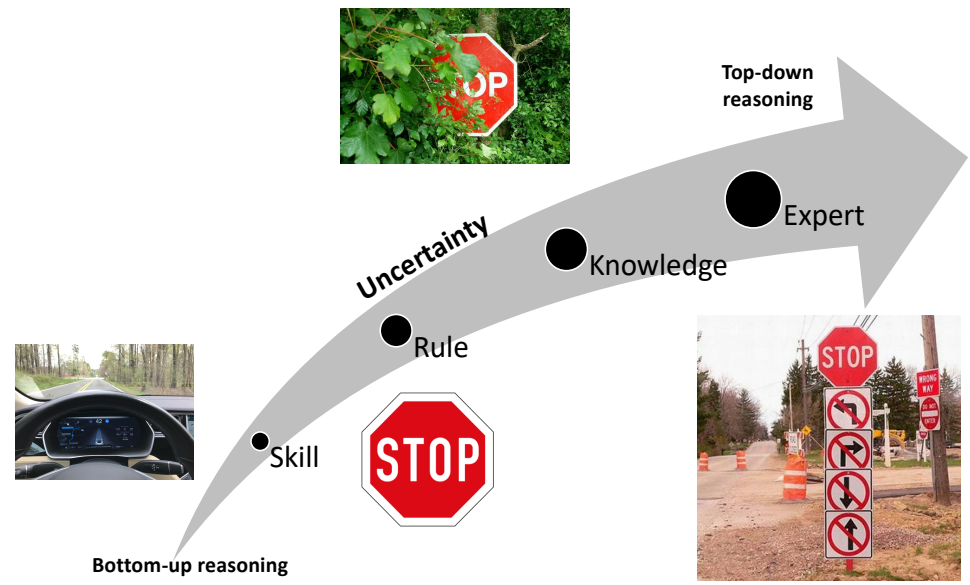
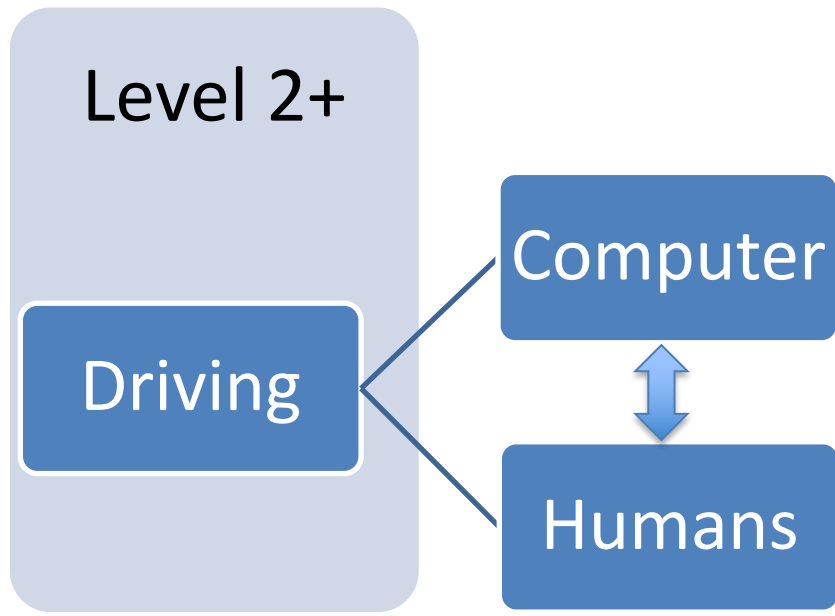


Tesla Model 3 Reliability in
Driver Alerting:
Assessing Human-Autonomy
Interaction in Driving Assist
Settings

Missy Cummings

Duke University

The Conundrum of Partial Autonomy



The Conundrum of Partial Autonomy

Level 2+

Driving

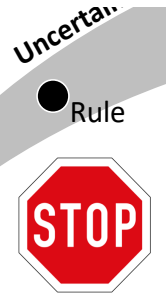
Computer

Humans



Bottom-up reasoning

Skill



Rule

Uncertainty



Top-down reasoning

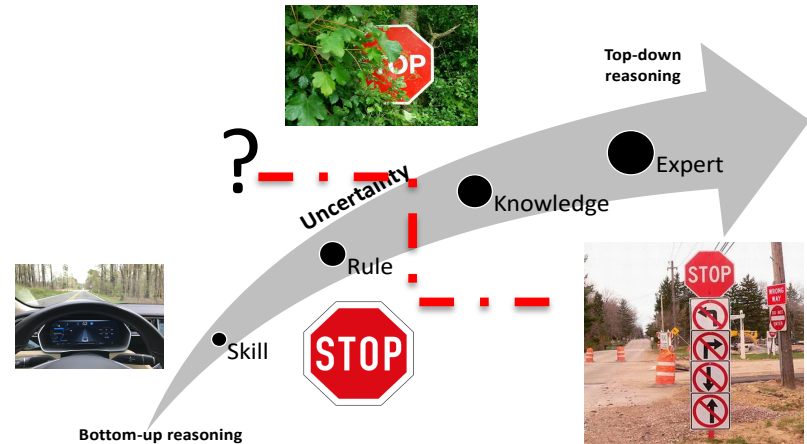
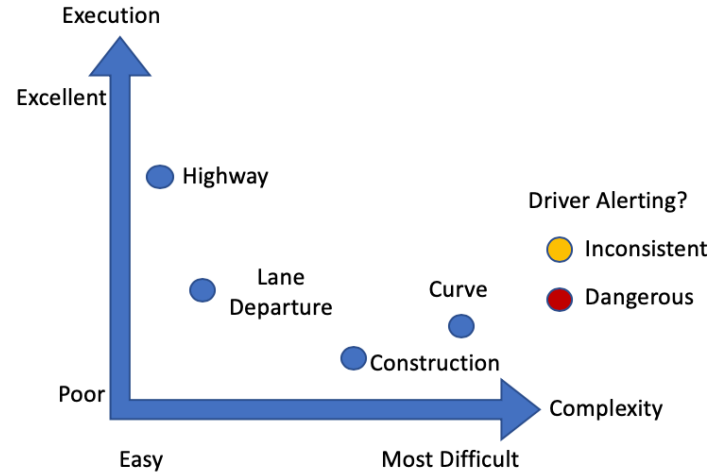
Knowledge

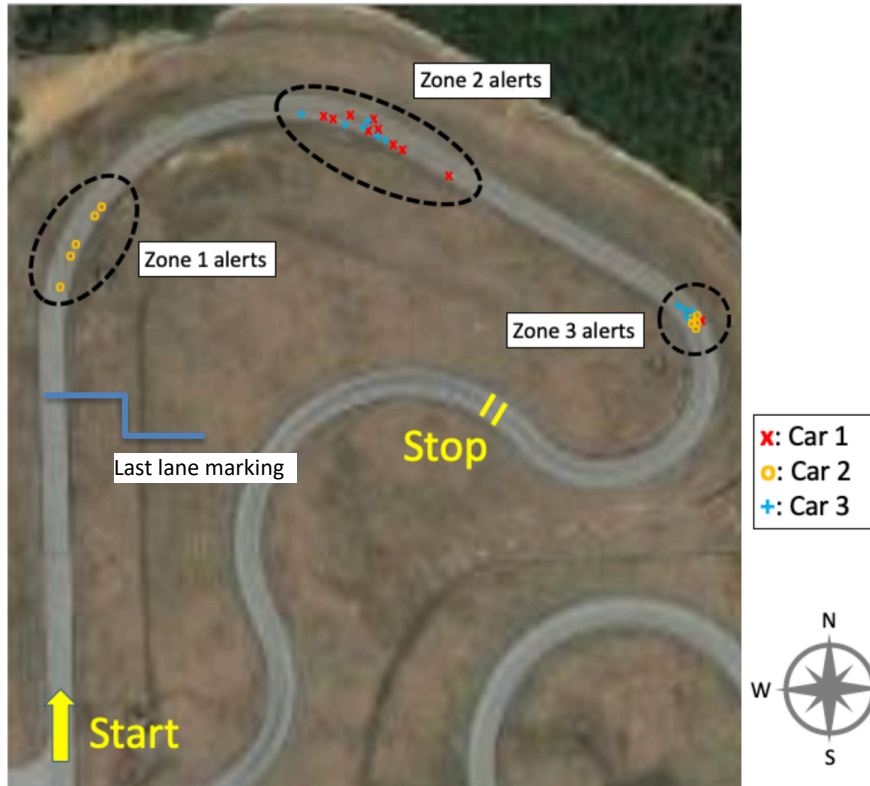
Expert

Uncertainty

Need consistent and timely handover alerting to maintain continuity

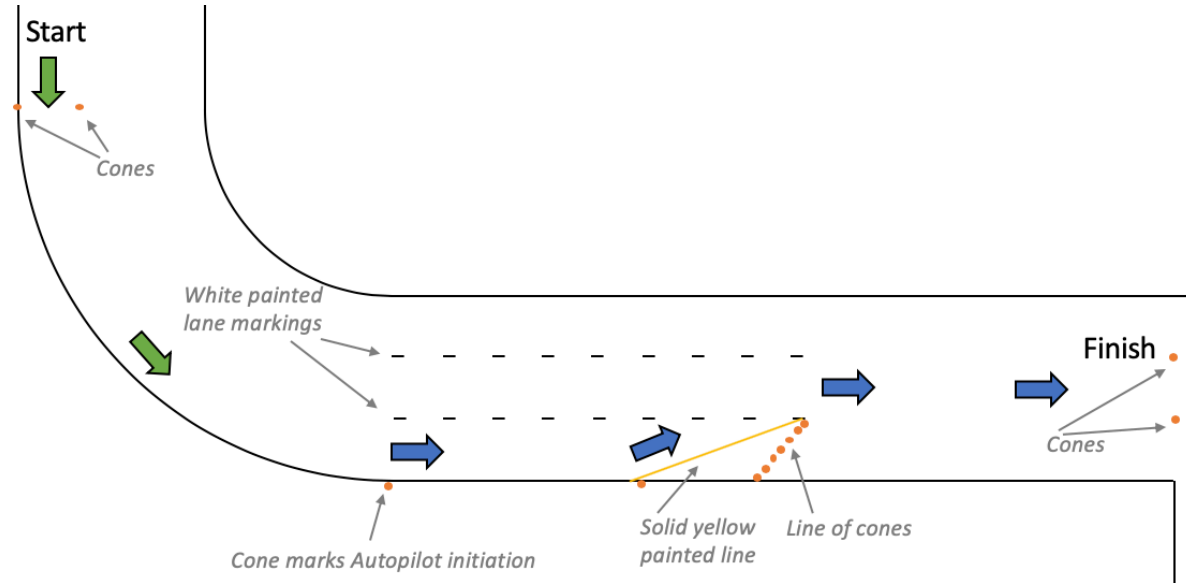
- 4 tests
 - Curve
 - Construction
 - Lane departure
 - Highway
- NCCAR track
- Three 2018 Tesla Model 3s randomly selected
 - 10 randomized runs each
 - 1 driver w/ 1 assistant
 - Confound between the car and the software version.
 - Could only control some internal settings
 - 6 hour window (11am-5pm in March)



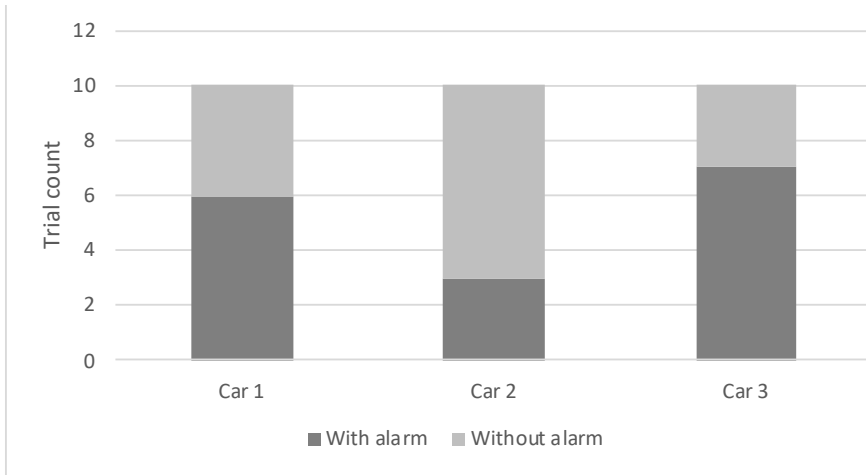
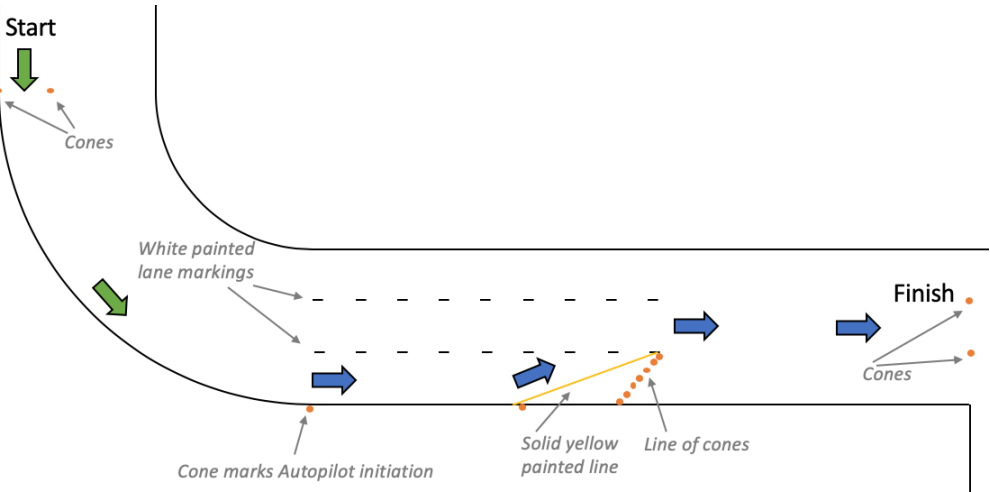


- Autopilot safely stopped the cars in all 30 trials.
- High variability for receiving 1st takeover alert (3 distinct clusters), but once initiated, consistent timing for 2nd and 3rd
- In 30% of trials, cars travelled 26s beyond LLM before warning the driver.
- Distances between LLM & initial alert could be as short as 43 ft (13 m), as late as 1255 ft (383 m)
 - Very inconsistent
- Some evidence that sun angle and brightness may influence perception systems

- Same 3 Teslas
 - Disabled Car 2's FSD visualization
 - Same times of day
- 10 runs each
 - Randomized
- 25 mph
- Autopilot initiated at lane lines
- 7 cones, painted yellow line

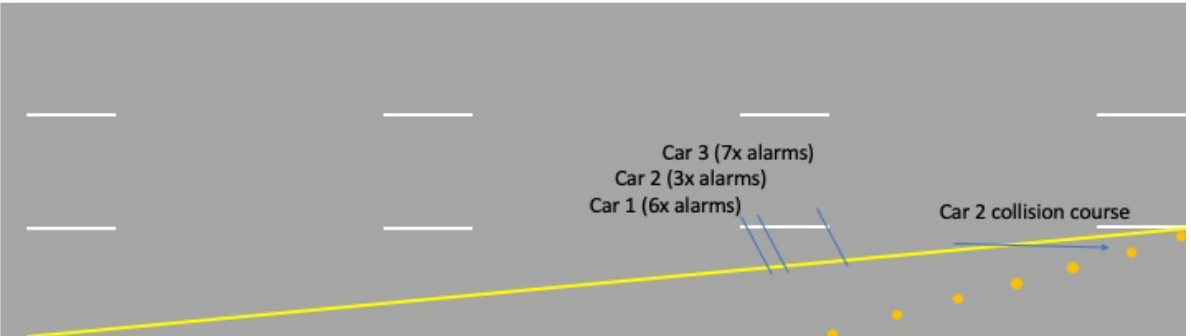


Construction Zone Test



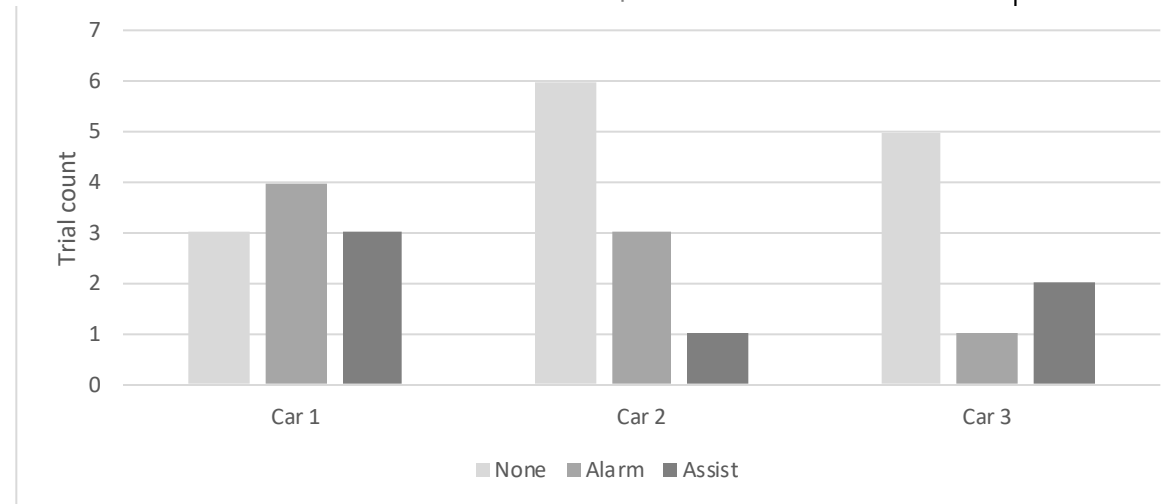
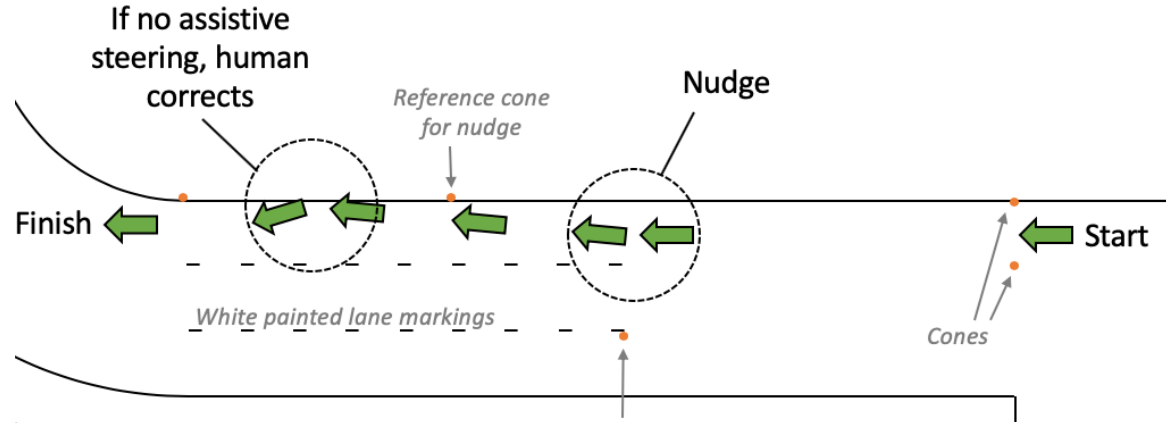
10 feet

Car 2 was full self-driving



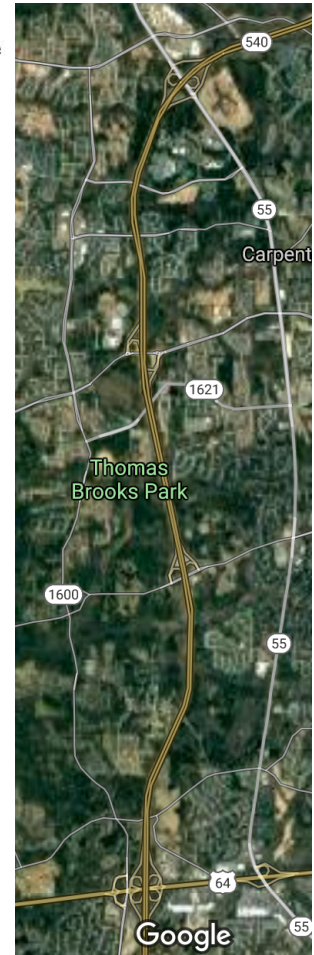
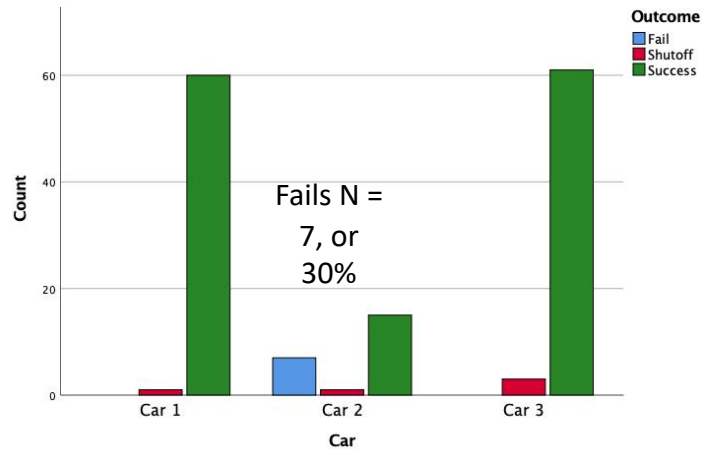
Emergency Road Departure Test

- Angle of wheel rotation measured from cameras, ANOVA with car & outcome (none/alarm/assist) as predictors. No statistical difference in wheel angle inputs.
- 50% trials would have ended with distracted driver off the road, only 21% had any active emergency steering.

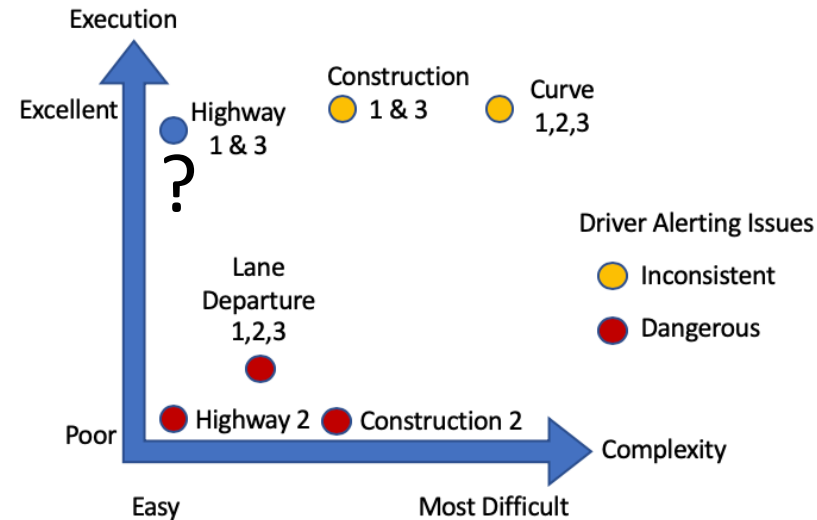


Highway Driver Monitoring Test

- 162 total events
 - FSD car was a problem
- Success, shutoff, failure
 - Driver responds to alert and autopilot continues
 - Driver responds to alert and autopilot shuts off unexpectedly
 - 3.6% of successful trials
 - Driver never alerted, car makes unsafe move
 - A failure ended that trial for safety
- While hands off alerting was generally consistent, 30s is a long time to not be paying attention at 70mph
 - Car 3: 43.8s at ~55mph & Car 1: 43.4s at ~63mph
 - Time to clear each alarm was consistent



- Perception systems for Cars 1 & 3 seemed consistent across tests
 - Sometimes good (const. & hwy), sometimes bad (lane departure)
- Autopilot handover alerting was all over the place for all 3 cars
 - Unexpected handovers can be critical under time pressure – mode confusion
- Driving monitoring system mostly consistent
 - Completely failed in 30% of Car 2 trials
 - Is linear time between hands-off notifications a good idea?
- Car 2 performance a mystery
 - Performed best in most difficult scenario, consistent in successful highway trials (roughly 1/3 of other cars) but was unsafe in 3 of 4 tests
 - Problems with software OTA updates could be a significant albatross
 - Are drivers being used for beta testing?



Questions?